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Domain 1 Marine Protected Area Preliminary Proposal PART B: Conservation Objectives

Delegations of Argentina and Chile

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ABSTRACT

This document contributes to the planning process for the designation of a Domain 1 MPA led by Argentina and Chile (SC-CAMLR-XXXVI/17 and SC-CAMLR-XXXVI/18). Particularly, this report summarizes the results and decisions taken in a series of international workshops specifically developed to assist in the Domain 1 MPA planning process, including the 2012 - First International Workshop held in Valparaiso, Chile, (WG-EMM-12/69); the 2013 Binational Workshop (Chile-Argentina) held in La Serena, Chile (WG-EMM-14/40), the 2015 Second International Workshop for identifying Marine Protected Areas (MPAs) in Domain 1 of CCAMLR held in Buenos Aires, Argentina (WG-EMM-15/42); and the 2016 Informal Workshop on Domain 1 MPA held in Bologna, Italy (WG-EMM-16/73).

This report has been compiled by the authors based on expert discussions held during the above workshops. The list of participants for these Workshops can be found in Annex 3. A revised version with a complete list of authors is proposed to be submitted to CCAMLR Science (SC-CAMLR-XXXVI/16).

INTRODUCTION

The aim of this document is to briefly compile in one single document the rationale behind the Domain 1 MPA preliminary proposal, including relevant information on conservation objectives and spatial layers. Further details on the several decisions made along the years can be found in papers previously discussed – WG-EMM-12/69, WG-EMM-14/40, WG-EMM-15/42, WG-EMM-16/73 – and EMM report (WG-EMM-16, paragraph 3.19). Specific technical details on variables, analysis and metadata can be found in Data Forms for each Conservation Objective uploaded at the Domain 1 MPA e-group.

Conservation Objective 1: important benthic habitats

This conservation objective seeks to protect a representative fraction of all benthic habitats present at Domain 1. As a result of the discussions arisen in the first two workshops, this objective was separated in ecoregions and habitat types based on the importance to distinguish the different benthic communities found in the same habitat type across ecoregions.

Ecoregions correspond to a large geographical area distinguished by the uniqueness of its morphology, geology, climate, flora and fauna. We have identified the ecoregion of South Orkney Islands (48.2), the northwestern Antarctic Peninsula and the southwestern Antarctic Peninsula, to distinguish the different communities found in a same habitat type across ecoregions.

Habitat types were identified through the benthic bioregionalization work developed by Douglass et al. 2011 (WS-MPA-11/23) and Douglass et al. 2014, based on physical proxies such as depth, seabed slope, water column or seabed temperature and primary productivity.

Large and complex data layers, such as benthic bioregionalization, in which each object is required to be protected, have been proved to have an effect in achieving consistent results (WG-EMM-16/73). Accordingly, the layer of benthic environment types was modified using only geomorph and depth features reducing the spatial objects to 67 categories, based on benthic ecoregions been included as separate objects and considering a dossier of data for Domain 1 (Douglass 2013).

Two layers based on domination of benthic organisms as a result of bottom fishing research from US cruises was agreed (WG-EMM-15/42). It was observed that benthic communities dominated by echinoderm are associated with warmer areas, whereas communities dominated by sponges are more common in colder regions. For this, the 0°C isotherm was considered a good proxy to identify these features, separating the Domain 1 in regions with temperatures above and below 0°C.

Ecoregions, habitat types and sea floor temperature correspond to a coarse approximation of the expected distribution of species, communities and ecosystems (Annex 1, Fig. 1). Therefore, the degree of protection is considered to be low (Annex 2, Table A). However, their inclusion is important in order to provide an adequate representativeness of benthic environmental variability within the Domain 1.

Conservation Objective 2: Representative examples of pelagic habitats

This conservation objective seeks to protect a representative fraction of all important pelagic habitats present at Domain 1.

It includes a single conservation object described by the pelagic bioregionalization, used to classify the environments across a region into a number of discrete classes, thereby providing a spatial and environmental subdivision of the study area (Raymond 2011). To provide an adequate representativeness Domain 1 was divided in Eastern and Western sections, and the pelagic ecoregions in north and south of the Antarctic Polar Front (APF), accounting for 16 pelagic bioregions (Annex 1, Fig. 2).

Accordingly, target protection for this conservation objective was considered to be low and was divided proportionally within three subregions: north of APF (northwestern area of Domain 1), south of APF, and East and West of the 50°W meridian (Annex 2, Table A).

Conservation Objective 3: Important benthic ecosystem processes

This conservation objective seeks to protect specific benthic features that contribute to the generation of predictable ecologic processes within Domain 1.

Three benthic habitats were identified as generating predictable ecosystem processes, involving two types of canyons and ice shelves. These objects were chosen because they are predictable high sources of productivity and are important for biodiversity (WG-EMM-12/69).

Canyons influence oceanographic processes, sediment transport, productivity and benthic biodiversity (Huang et al. 2014), but may perform different ecological functions based on their physical characteristics in relation to the shelf and slope. Shelf-incising canyons extend across the shelf and may therefore terminate closer to coastal areas, whereas blind canyons are confined to the continental slope and terminate blow the shelf-break (Huang et al. 2014). In 2015, a new geomorphic data describing submarine canyons based on updated bathymetry was included (Harris et al. 2014), and canyon layer was built to include two types, shelf-incising and blind (Annex 1, Fig. 3).

<u>Benthic areas under ice-shelves</u>: Persistent ice-shelves are a special habitat type with a unique ecosystem underneath. The potential collapse of ice-shelves with global warming will have profound effects on the ecosystem beneath, previously protected, with potential increase for primary and secondary productivity; it will also be an area prone to be colonized for new species; these are areas with significant scientific interest. Ice-shelves detected for Domain 1 were presented in WS-MAP-11/17.

Other predictable ecosystem processes are the up/down-welling and mixing areas, as they are considered to be high sources of productivity and are important for biodiversity (WG-EMM-12/69). These processes were decided not to be included as separate data layers as they are already considered in conservation objectives 1 and 2 as part of the benthic and pelagic models by Douglass et al. (2014) and Raymond (2011), respectively.

Regarding target levels, it was used a medium to high value for those conservation objectives that contribute to concentrate primary or secondary productivity (canyons), or that constitute a unique habitat with unique biodiversity (e.g. benthic ice-shelves) (Annex 2, Table A).

Conservation Objective 4: Large-scale pelagic ecosystem processes

This conservation objective seeks to protect large-scale, pelagic ecosystem processes, spatially predictable over the years.

Four large-scale pelagic processes predictable in space/time have been identified, which represent foreseen features for primary productivity or food concentration (Hofmann and Hüsrevoglu 2003; Atkinson et al. 2008; Siegel et al. 2013).

<u>Predictable highly productive areas – surface</u>: As a proxy measure for areas with predictable high primary productivity, the persistent summer Chl-a derived from multiyear satellite images was used. It was agreed that all areas with values equal or greater than 0.11 mg/m^3 would be considered for the analysis (Annex 1, Fig. 4).

<u>Frontal features</u>: The sACCf was selected because it separates warmer ACC water to north, associated with the ecological division of the krill/copepods dominated ecosystems. The frontal zone area was estimated as the mean position of sbACCf and nbACCf, plus 30 km buffer on sbACCf. The frontal zone was further divided into 3 sectors, based on expert opinions about the different ecosystems east-west of the 50°W meridian and north-south of Anvers Island. For example, the southern section of the frontal zone is an area of high *E. superba* larvae production. Accordingly, each area will receive an equal % of protection (Annex 1, Fig. 4).

<u>Marginal ice zone</u>: The ice edge is considered to determine the distributional pattern of several zooplankton species, as well as marine mammals and birds. It is also a good proxy for the distribution of many species breeding in association with it (e.g. pack-ice seals). The climatologically position of the marginal ice zone (MIZ) during summer and winter period was characterized and included in the analysis: (i) February, when sea-ice extent is minimized and (ii) August, when sea-ice extent is maximized (Annex 1, Fig. 4).

<u>Polynyas</u>: These are persistent features that play a critical role during winter in the local flux of nutrients, attracting small and large animals. Polynyas where included each as a single, undivided object with no buffer around them (Annex 1, Fig. 4).

All of the above conservation objects are representative of spatially predictable process contributing to the productivity in Domain 1. Accordingly, the degree of protection was agreed to be medium to high (Annex 2, Table A). For marginal ice zone the protection desired was medium-low (Annex 2, Table A) as it is only a proxy for the distribution of predators.

Conservation Objective 5: Important (spatially constrained/predictable) areas for mammals and birds life-history

This conservation objective seeks to protect the distribution of marine mammals and birds during critical stages of their life-history.

Seabirds and marine mammals are important predators of the Antarctic ecosystem. As they forage at sea, they are vulnerable to the potential impact of local activities, such as fisheries or regional effects like Climate Change. In the western Antarctic Peninsula an ongoing decline in the breeding populations of Adélie (*Pygoscelis adeliae*) and chinstrap (*P. antarctica*) penguins have been recorded while an increase in the population of gentoo penguins (*P. papua)* and the recovery of whales, the largest and most important krill consumers were observed in the same area (Carlini et al. 2007, 2009; Trivelpiece et al. 2011; Novacek et al. 2011; Lynch et al. 2012; among others).

Krill fishing is concentrated in Subareas 48.1 and 48.2 and it has been proved to have a high degree of spatial variability between and within years (Capurro et al. WG-EMM-17/22; Santa Cruz et al. WG-EMM-16/52). Moreover, in the last seasons it has been observed a spatial aggregation of the fishery in areas near the coast (Trathan and Hill WG-EMM-16/17). Consequently, spatiotemporal overlap between top predators (pygoscelid penguins and fur seal) was observed throughout the Antarctic Peninsula and South Orkney Islands region, including breeding colonies and distant areas where recent fishing activity has concentrated (Hinke et al. 2017). Also, Weinstein et al. (2017) have identified whales foraging areas in the Gerlache Strait and the Bransfield Strait/Mar de la Flota; the latter was identified as the most used SSMU by the krill fishery (APBSW). They found a spatial overlap between whale presence and concentrated fishing activities. Bearing in mind the future projection of an increase in the krill fishery activities, the protection of krill fishing predators become one key element to be considered in the Domain 1 MPA preliminary proposal.

Many of these krill-dependent species are considered as bio-indicators of the state of the ecosystem by CCAMLR, existing data is collected in a systematic way across years and locations, and there are future monitoring plans in cooperation with different members. Currently, work to develop a Feedback Management Strategy (FBM) for the krill fishery is under consideration, which could include changes to the spatial and temporal operations of the fishery in Subareas 48.1 and 48.2 in response to changes in predator-derived indexes. For this reason, it will be necessary to harmonize the MPA proposal with the development of the FBM or any other strategy agreed by the Commission in a manner consistent with the objectives of the Convention.

This objective considers information for land based predators colonies; the foraging areas of penguins and Antarctic fur seals during breeding; the foraging areas of whales, seals, and penguins during non-breeding period; and where information in some areas is scarce, the distribution of prey, as a good proxy for important feeding areas.

All this information led to the inclusion of spatial data layers for a) foraging distribution during breeding, b) prey distribution, and c) foraging distribution during non-breeding periods. All data was reviewed to ensure that shapefiles available for Marxan analysis include the best available information.

a) Foraging distributions of Central Place Foragers during breeding season:

This objective seeks to protect the main foraging grounds of known top predators during their reproductive season. The distribution of marine mammals and birds during their breeding, when they behave as Central Place Foragers, was considered a critical time during their life-history and important to protect. Data for penguins including pygoscelid species, emperor and macaroni penguins, as well as for Antarctic fur seal, was included in the analyses.

Colony locations and number of pygoscelid penguins breeding pairs were obtained from an extensive review of publish and non-publish material, largely compiled by the British Antarctic Survey, and complemented with information from other CCAMLR Member Countries, including the USA, Argentina and Chile and lately compared with Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD, Humphries et al. 2017) and the Important Birds Areas Report (Harris et al. 2014). Only pygoscelid colonies, for which at least 10 breeding pairs have been estimated in the last census data available, were considered. The locations of Emperor Penguin (*Aptenodytes forsteri)* colonies (Smyley Island and Snow Hill Island) were obtained from Fretwell et al. (2012) and Libertelli and Coria (2014). Emperor penguins have a variable diet across Antarctica (including fishes, crustaceans and squids), and in the Weddell sea krill was found to be the main component of this specie´s diet representing up to 67% of stomach content (Ratcliffe and Trathan 2011). For macaroni penguins (*Eudyptes chrysolophus*) all known breeding sites in the Antarctic Peninsula Region were revised (Naveen and Lynch 2011).

Regarding *colony buffer areas*, associated with foraging range, they were represented by a half-circle rather than a full circle (WG EMM-15/42), based on observations of foraging distributions from a central place: foraging generally radiate from the colony in one direction over the shelf and towards the shelf break, and are typically constrained by land masses in the opposite direction. Exceptions may occur on small islands (e.g. Powell Island) or on peninsulas and headlands of islands (Signy Island) where marine habitat is available throughout larger sectors; for these exceptions, full circles were agreed to be used (Annex 1, Fig. 5a).

Foraging range for the penguin species was defined as the inflection point in the cumulative frequency distribution of birds tagged with satellite transmitters during brood and crèche periods. Information regarding colonies at the South Shetland Islands and the Antarctic Peninsula was derived from birds tagged at Admiralty Bay (Copa) and Cape Shirreff colonies studied by the

US-AMLR program, and represented by the 75% cumulative distribution of the maximum foraging range of the birds tagged (Table 1, Fig. 5a).

Foraging range of penguins breeding at South Orkney was obtained from birds tagged at Signy Island by the BAS, when available. Data for chinstrap and Adélie penguin breeding was obtained from WG-EMM-02/33 (Table 1).

Alternative methods exist to estimate the size and location of the colony buffer zone including habitat modelling and cost-distance analysis. Although these analyses could provide greater resolution in potential foraging areas for each colony during the summer breeding season, preliminary results of habitat modeling for pygoscelid penguins in Subarea 48.1 do not differ significantly from estimations used here (Trathan et al. WG-EMM-17/34).

For emperor penguins, a 100 km buffer radius was considered based on the foraging areas of other colonies (Ratcliffe and Trathan 2011). In the case of the Snow Hill colony of emperor penguins, it was noted that although this colony is placed outside Domain 1, its 100 km buffer enters this area. For macaroni penguins, the 50 km buffer was derived from averaging the foraging radius observed during chick rearing at South Georgias (Barlow and Croxall 2002; Trathan et al. 1998) (Annex 1, Fig. 5a).

Distribution of the breeding colonies of Antarctic fur seal was obtained from the last AMLR census (2007/08). Only the colonies with at least one pup in the last census were considered (Goebel et al. 2008). The foraging range for this species from pup birth to weaning was derived from the inflection point on the cumulative distribution of the maximum foraging range of breeding females tagged at Cape Shirreff by the US-AMLR program (Table 1, Fig. 5a).

Table 1: Species, colonies and buffers (km) used for estimating foraging habitat during breeding season.

Species	Colony	Buffer radius (km)	According to
Adélie penguin (South Orkney)		100	WG-EMM-12/69 and WG-EMM-14/40
Adélie penguin (South Shetland and Antarctic Peninsula)	Admiralty Bay Hope Bay	50	WG-EMM 12/69 and 14/40
Chinstrap penguin (South Orkney)		45	2015
Chinstrap penguins (South Shetland and Antarctic Peninsula)	Cape Shirreff Admiralty Bay	25	WG-EMM-12/69 and WG-EMM-14/40
Gentoo penguin (South Orkney)		45	2015
Gentoo penguin (South Shetlands and Antarctic Peninsula)	Cape Shirreff Admiralty Bay	25	WG-EMM-12/69 and WG-EMM-14/40
Emperor penguin		100 (*)	2015
Macaroni penguin		50	2015
Antarctic fur seal (South Shetlands)	Cape Shirreff	75	WG-EMM-12/69 and WG-EMM-14/40

(*) Snow Hill colony of emperor penguins: this colony is placed outside Domain 1, but its 100 km buffer enters this area.

Pack-ice seals were not considered as they do not forage during the lactation period. Southern elephant seals were assimilated within this category too. Data for other seabirds is scarce, particularly data referring to their breeding distribution and thus, were not considered.

Regarding conservation targets, due to feeding restrictions of central foragers, it was agreed to use medium-high protection levels for analyses (Annex 2, Table A).

b) **Prey distributions**

This object seeks to protect the distribution of key species for predators. Information of the distribution of marine mammals and birds when they are not restrained by breeding is less abundant. However, the data available suggests that they are highly mobile and able to track their prey over long distances. Even further, many species leave the Domain 1 area (and the Convention Area) during winter, e.g. Antarctic fur seals and whales. In this sense, the distribution of their main prey is a proxy for identifying their main foraging grounds.

Four prey taxa for which data is available were identified and rasters characterizing the spatial variation of their densities were used as data layers. Data for crystal krill (*Euphausia crystallorophias*), *Thysanoessa macrura* and salps (*Salpa thompsoni*) were developed from zoooplankton density data collected by U.S. AMLR Program during net tow surveys (1993-2011) and PAL LTER and German Zooplankton Cruise (2011). Adult krill (*Euphausia superba*) data was compiled from the KRILLBASE (Atkinson et al. 2017) using the standardized density (method described in Atkinson et al. 2008) for the 1993-2011 period. Only adult organisms were considered. Distribution of krill nurseries are considered in a separate objective (Objective 7). (Annex 1, Fig. 5b-d) Further details can be found in Data Form for objective 5b.

As the distribution of preys is only a proxy for identifying predators' main foraging grounds, it was decided to be protected using a medium target (Annex 2, Table A).

c) **Foraging distribution during non-breeding season**

This objective seeks to protect the main foraging grounds of known top predators during their non-reproductive season. Different studies suggest that winter survival rate, particularly of juveniles is a key factor explaining current declines observed in some penguin species (Hinke et al. 2007; Carlini et al. 2009; Trivelpiece et al. 2011). Likewise, breeding population size during spring is largely dependent on foraging success during the previous winter.

Most Antarctic pinnipeds (except for fur seals) have a capital reproduction. This means that during the gestation period they build up fat reserves that they use during the lactation period. In Antarctic pinnipeds the gestation period lasts from summer to summer (Forcada 2007). It is worth noting that a large influx of male Antarctic fur seals from South Georgias into Domain 1 occurs in late summer/early autumn. Accounting for their main foraging areas was considered important for the MPA planning process, given Antarctic fur seals are a potentially large, transient population of krill-dependent predators. Current tracking data that include male fur seals from Cape Shirreff, Livingston Island, demonstrate that these animals use habitats throughout Domain 1, including marginal ice zones. Using a proxy habitat layer based on marginal ice zones for this transient population was considered.

In the case of whales, many species annually migrate to Antarctic waters to exploit the rich krill resources. Here, whales feed and build up fat deposits to survive their long migration to subtropical and tropical waters where they breed but hardly feed for the rest of the year (Lockyer and Brown 1981).

In Antarctic waters, three different ecotypes of Killer whales (Type A, B1 and B2) have been described based on morphology and prey specialization. In the Antarctic Peninsula, there appears to be two size variants of type B killer whales—a large form that wave-washes seals off ice floes (Visser et al. 2008) and takes an occasional Antarctic Minke whale, and a smaller form that forages in more open water. The smallest version has been observed in the Gerlache Strait feeding on penguins (Pitman and Durban 2010).

Humpback whales (*Megaptera novaeangliae*) have recovered to the extent of becoming the most numerous whale species in the region (Herr et al. 2016). Their distribution is related to the distribution and abundance of krill (Nowacek et al. 2011) since krill is their primary food source (Nicol et al. 2008).

For this objective, tracking data for several penguins, pinnipeds and cetaceans were considered (Table 2). Tracking data for pygoscelid penguins (Adélie, gentoo and chinstrap), cetaceans (Humpback whales, Minke Whales, Type A, Type B1, and Type B2 killer whales), and 4 pinniped species (Antarctic fur seal, Weddell seal, elephant seal and leopard seal) have been processed according to a method described by Hinke et al. (2012) which interpolates the time spent by an individual within an area and estimates alternatives paths for connecting positions derived from satellite links (Annex 1, Figs. 5f-g). The rationale for this relates to the need to standardize estimates of habitat utilization from different tagging locations, so that the identification of locations of high-use winter distribution locations is not biased by data from tagging locations with larger sample sizes and longer deployment durations. Further analyses were performed in order to calculate the intensity of use of Domain 1 by each species, given that their distribution and use of space is not even across species (more details can be found in Data Form for Objective 5c).

Table 2: Species and tagging locations used for estimating non-breeding habitat use, based on tracking data.

SPECIES	Colony (No. years)	Months (No. ind)	Data owner
Adélie penguin	Admiralty Bay (1)	April-August (1)	US-AMLR$_1$
	Northern Antarctic Peninsula Hope Bay/ Esperanza (2)	March-April (10)	ARG-IAA
	South Orkney Islands	April-August	UK-BAS
Chinstrap penguin	Cape Shirreff (4)	April-September (33)	US-AMLR$_1$

	Admiralty Bay (3)	April-July (13)	US-AMLR[1]
	South Orkney Islands	April-August	UK-BAS
Gentoo penguin	Cape Shirreff (2)	April-September (25)	US-AMLR[1]
	Admiralty Bay (1)	April-July (1)	US-AMLR[1]
Antarctic fur seal	Cape Shirreff (5)	April-September (63)	US-AMLR[1]
Weddell seal	Cape Shirreff (1)	April-September (6)	US-AMLR[1]
Leopard seal	Cape Shirreff (3)	April-September (12)	US-AMLR[1]
Crabeater seal	WAP (3)	April-November (44)	UCSC[3]
Southern Elephant seal	Cape Shirreff	February-October (54)	UCSC/US-AMLR[3]
	Potter Peninsula (4)	December-July (49)	AWI (GR)-IAA[4]
Humpback whales	WAP	January-Sept (22)	US-AMLR[2]
Minke Whales	WAP	February-March (14)	US-AMLR[2]
Killer Whales T A	WAP	Feb-April (9)	US-AMLR[2]
Killer Whales T B1	WAP	January-March (8)	US-AMLR[2]
Killer Whales T B2	WAP	January-March (23)	US-AMLR[2]

[1]Hinke et al. 2012 and Hinke et al. 2017
[2]Data coordinated by Bob Pitman, U.S. AMLR Program
[3]University of California-Santa Cruz (Dan Costa)
[4]Data owner-Horstmann (AWI). Data available in PANGAEA - Data published in De bruyn et al. 2014

Regarding conservation targets, similar to foraging distribution during breeding and directly related to it, as breeding population size depends on foraging success during the past winter, it was agreed to use medium-high protection levels for analyses (Annex 2, Table A).

Conservation Objective 6: Important (spatially constrained/predictable) areas for fish life cycles

This objective seeks to protect the areas of occurrence of notothenioid fish populations in the southern Scotia Arc, which were overexploited by the commercial fishery in the South Shetland and South Orkney Islands and the tip of the Antarctic Peninsula during the late 1970s and the 1980s (Tin et al. 2009). In general, these regions have similar ichthyofaunal communities and were affected by a similar history of resource depletion. As a consequence, finfish fisheries in Subareas 48.1 and 48.2 were banned in 1990 (CM 32-02), and stocks of several notothenioid species are still in the process of recovery (Barrera-Oro et al. 2000; Jones et al. 2000; Kock and Jones 2005; Jones and Kock 2009; Kock et al. 2012; Marschoff et al. 2012, Barrera-Oro et al. 2017).

<u>*Object 6.a. Spawning/recruitment areas of commercially exploited notothenioid species*</u>

This objective seeks to protect nursery areas of notothenioids, particularly marbled notothenia (*Notothenia rossii)*, green notothenia (*Gobionotothen gibberifrons)* and ice fish (*Chaenocephalus aceratus)* and as a co-effect, the main feeding areas of Antarctic shags, birds with a negative population trend at certain monitored colonies in the South Shetland Islands. At the same time, the coastal macroalgal communities in the neritic domain down to 50 m deep, which provide a valuable habitat and refuge for benthic and pelagic animals, would also be protected.

This object of conservation covers the breeding area of juvenile populations including early stages of commercially fished demersal notothenioid species, such as*, N. rossii*, *G. gibberifrons* and *C. aceratus* which occur in the inner/inshore neritic fraction of the shelf. In general, notothenioids have pelagic larval-postlarval stages and, although its targeted catch is prohibited in the Subareas mentioned, there is a catch rate of these early stages in the krill fishery (WG-EMM-13/38; WG-EMM-14/31 Rev. 1). Juvenile stages of *N. rossii* and *G. gibberifrons* from 1-2 to 6-7 year old, and other notothenioids such as *C. aceratus* inhabit preferentially coves, bays and shore waters down to 150 m deep (Kock 1992; Marschoff et al. 2012). Rocky coastal areas are colonized by a dense cover of macroalgae species (Wiencke and Clayton 2002; Quartino and Boraso de Zaixso 2008). The macroalgal assemblages are mainly distributed from 0 down to 30 m deep (Quartino et al. 2001, 2005), especially the dominant large brown *Desmarestiales* species are commonly used as habitat and refuge for pelagic larval and post-larval stages of fish (Barrera Oro et al. 2012).

Object 6b. Occurrence areas of historically commercially exploited fish populations.

This object of conservation covers the area of geographic distribution of commercially exploited notothenioid fish in the offshore fraction of the shelf within Domain 1 region. The fish species to be protected are listed in CM 32-02 for the areas surrounding the South Shetland Islands Archipelago, including the northernmost Elephant Island, Joinville Island in the tip of the Antarctic Peninsula and the South Orkney Islands. The issue of fish by-catch in the krill fishery has been largely discussed in the compass of CCAMLR since the mid-1980s; one of the most frequently species caught in offshore waters is *C. gunnari* (Kock and Jones 2012). However, although research on this matter is progressing, the actual effects of the early life stages of Antarctic fish by-catch on their populations are still unknown.

Four files were agreed to be included in the analysis: 0-150 m North 64°S, 150-500 m North 64°S, 0-150 m South 64°S and 150-500 m South 64°S (Annex 1, Fig. 6).

Layer strata 0-150 m depth: Some notothenioid species such as *N. rossii* and *G. gibberifrons* and the icefish *C. aceratus* spend early stages of their life cycles in inshore waters. These fish were target or by-catch species affected by the commercial finfish fisheries described in CCAMLR CM 32-02, and could potentially be affected by the current krill fishery.

Layer strata 150 to 500 m deep: this layer was included in order to protect the whole populations of notothenioids, which are mainly distributed down to this depth, included the juvenile stages of *Dissostichus*s pp. One of the main commercial exploited species, also included in CM 32-02, the mackerel icefish *C. gunnari*, occurs in this depth stratum during its whole life cycle. In this way, both layers were managed as two conservation objects (a and b) with distinct conservation targets.

A Southern limit for both 0 to 150 m and 150-500 m layer south of 64°S was established. It was decided to extend this limit to the southern part of Domain 1 along the western Antarctic Peninsula, in order to protect the entire distribution of important life cycle areas for these species, and in particular the juvenile stages of notothenioids which could face a potential threat from e.g. future activities of the krill fishery (Kasatkina 2006).

The target conservation levels were set according to the past and future threats related with industrial exploitation, acknowledging that levels in layers covering areas under the influence of historical (finfish) and current (krill) commercial fisheries (North of 64°S) are higher than those in not affected areas (South of 64°S). Thus, the conservation target proposed were high (80%) for layers 0-150 m North 64°S, medium (50%) for 150-500 m North 64°S, and low (20%) for both 0-150 m and 150-500 m South 64° (Annex 2, Table A).

Conservation Objective 7: Important (spatially constrained/predictable) areas for zooplankton life cycles

This conservation objective seeks to protect the spawning/recruitment areas of key zooplankton species. The rationale for the inclusion of the krill nurseries is to protect the larvae, therefore a "source" of krill, in areas where it has been stated a reduction in krill abundance related to the effects of climate change (Atkinson et al. 2004), changes in fishery dynamics (Kawaguchi y Nicol 2007; Nicol et al. 2012; Kasatkina et al. 2013; Silk et al. 2014) and where during the last years, recent catches by the krill fishery in Subareas 48.1 have reached limits set by CCAMLR resulting in the early closures in 2016/17, 2015/16, 2014/15, 2013/14 and 2009/10 (monthly fishery report Nº 8 (2017) and Krill Fishery report 2016).

Krill nursery areas, including data for the Gerlache Strait, West Scotia Sea, Weddell Sea and Bellingshausen Sea were characterized based on different publications (see table in Dataform Objective 7). After hatching in deep water, the larvae develop while ascending. During their ascent, larvae are advected both onto the shelf and to the NE (along the Antarctic Circumpolar Current (ACC)). These two pathways are considered possible sources of krill larvae in the Gerlache Strait, but production within the Strait itself is also thought to occur. Huntley and Brinton (1991) concluded that the Gerlache Strait is a nursery area. Also, it is generally thought that many krill larvae found near the northeastern tip of the Antarctic Peninsula and in the Weddell-Scotia Confluence originate from the Weddell Sea (Capella et al. 1992). There have been many observations of larvae in the eastern Bellingshausen Sea, including observations made during the 1993-2013 LTER surveys showing highest densities offshore and to SW (Frazer et al. 2002).

The importance of the areas where Circumpolar Deep Water (CDW) intrudes onto the continental shelf is described by Piñones et al. (2013): "The occurrence of juvenile and medium-size krill along the inner shelf may result from local inputs in areas of the shelf where the shelf is deep (Brinton 1991; Hofmann et al. 1992) and CDW is present, which allows completion of the descent−ascent cycle (Hofmann and Hüsrevolu 2003). The clockwise surface circulation over the shelf and onshore flow at depth (Smith et al. 1999; Dinniman and Klinck 2004) may facilitate transport of krill larvae to the inner shelf."

Krill nursery areas (areas with high densities of larvae up to Furcilia III) have been identified in association with waters from the ACC in the Bellingshausen Sea and South Shetland areas, close to the continental slope. Also, krill larvae in the South Orkneys and Weddell Sea area have also been reported as related with the Weddell Scotia Confluence, but recent cruises of the Puerto Deseado (2011 to 2014) have shown a significant variability in the abundance of krill larvae in these areas in relation with historical values. On the other hand, it was observed the high densities encountered in the Gerlache Strait as well as their constant presence in a definite location across the years (probably arising from the flux of ACC waters towards the shelf) and the role of the Bellingshausen gyre as originating krill populations along Domains 1 and 3. For these reasons, some nursery areas were further divided and eight files were decided to be included in the analysis: SW and NE Bellingshausen Sea, South Shetland and South Orkney for the Scotia Sea, Weddell Sea, Gerlache Strait, and CDW intrusions in west shelf and ACC (Annex 1, Fig. 7).

Related to the conservation targets (Annex 2, Table A), nursery areas in the west Scotia Sea, Weddell Sea and Bellingshausen Sea were allocated low target values. Given the importance of the krill nursery in the Gerlache Strait, conservation target was agreed to be high (WG-EMM-15/42).

Conservation Objective 8: Rare or unique habitats/features

This conservation objective seeks to protect rare or unique geomorphic habitats.

This objective corresponds to a unique geomorphological feature: seamounts, either isolated or forming seamount chains ('seamount ridges' in Douglas et al. 2011). Seamounts hold relevant marine biodiversity in what it is characterized by high species richness, and while endemism might be lower than previously assumed (Clark et al. 2010), isolated seamount systems may harbor many endemic species not found in the surrounding deep sea (WG-EMM-14/40).

Seamounts were divided between two ecoregions (Antarctic Peninsula and South Orkney Islands). A seamounts layer was generated using geomorphic data based on bathymetry from the Global Seafloor Geomorphology dataset (publicly available from www. bluehabitats.org, and described in Harris et al. 2014). This layer includes all of the seamounts and seamount ridges. Seamounts were classified into three conservation objects, according to depth (bathome) and geographic location (ecoregion), using the Douglass et al. 2014 environment types: Seamounts and seamount ridges shallower than 2000 m depth (occurring in all ecoregions), Seamounts and seamount ridges deeper than 2000 m depth occurring in the South Orkney Islands ecoregion, and Seamounts and seamount ridges deeper than 2000 m depth occurring in the Antarctic Peninsula ecoregion (Annex 1, Fig. 8).

About conservation targets and taking into account that major threats to seamount’s biota are fisheries concentrated in depths up to 2000 m, it was proposed to use different levels of protection, establishing high conservation targets for shallower seamounts and lower values for deeper ones (Annex 2, Table A).

FURTHER CONSIDERATIONS

In order to identify the most efficient Domain 1 MPA model, considerations were given to some areas that are already protected by the Antarctic Treaty System.

Southern Shelf South Orkney Islands Marine Protected Area (SS SOI MPA): It was included in the analyses to assist in the identification of Domain 1 priority areas for conservation taken into account the marine protection already given by the SS SOI MPA according to CCAMLR CM 91-03.

Vulnerable Marine Ecosystems (VME): They were also included in the analyses as they represent sites with highly diverse benthic communities that are already protected by CCAMLR CM 22-06 and CM 22-07.

Special areas following ice-shelf retreat or collapse in Statistical Subareas 48.1, 48.5 and 88.3: the generation of the Domain 1 MPA model also considered the location of ice-shelves and the possible protection of the marine environments underneath them once such ice-shelves retreat or collapse, according to the CCAMLR CM 24-04.

Antarctic Specially Protected (ASPA) and Managed Areas (ASMA): Several protected areas with marine components already protected by ATMC Resolutions and by CCAMLR CM 91-02 were also included in the analyses (ASPAs 144, 145, 146, 149, 151, 152 and 153; ASMAs 1, 4 and 7). For more information on these areas please refer to ATS webpage (www.ats.aq).

Other aspects of the design of this Domain 1 MPA that were taken into account include the possible identification of Reference areas for scientific study and their contribution to strategies such as the Feedback Management Strategy (FBM) and risk assessment analysis. For instance, it is recognized the importance of reference or control areas to assess the potential impact of the krill fishery on krill-dependent species. In this sense, it could be proposed to classify existing ecosystem monitoring programs (CEMP and others) according to the existence of past and present fishing activities within the foraging range of the studied species (Adélie, gentoo, chinstrap and macaroni penguins and the Antarctic fur seal). Interestingly, the LTER study grid has never been subjected to fishery and it could be proposed as a reference area for assessing changes in the ecosystem in the absence of fishing. The identification of priority areas for conservation could also assist in the development of FBM or other strategies agreed by the Commission.

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Annex 1: Spatial distribution of conservation objectives and objects considered for the Domain 1 MPA proposal. Further technical details on methods, variables and metadata can be found in Data Forms for each objective uploaded to the Domain 1 MPA e-group.

Conservation Objective 1: Benthic important habitats

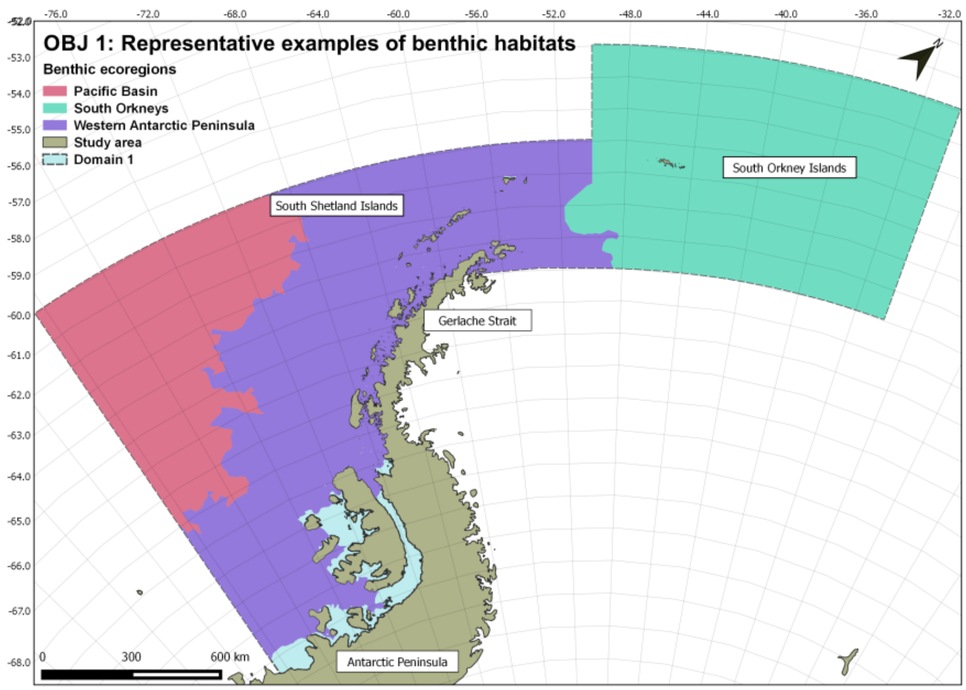

Figure 1a: Benthic Ecoregions as defined in Douglass et al. 2011.

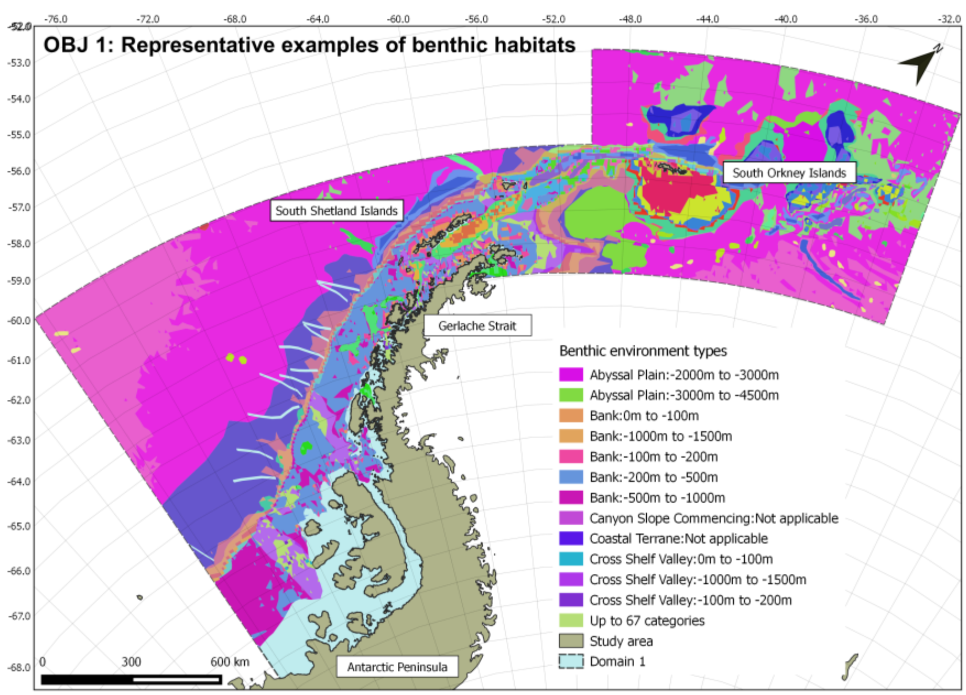

Figure 1b Representative examples of benthic habitats based on Douglass et al. 2011 and slightly modified according to MPA Dossier data for Domain 1 (Douglass 2013).

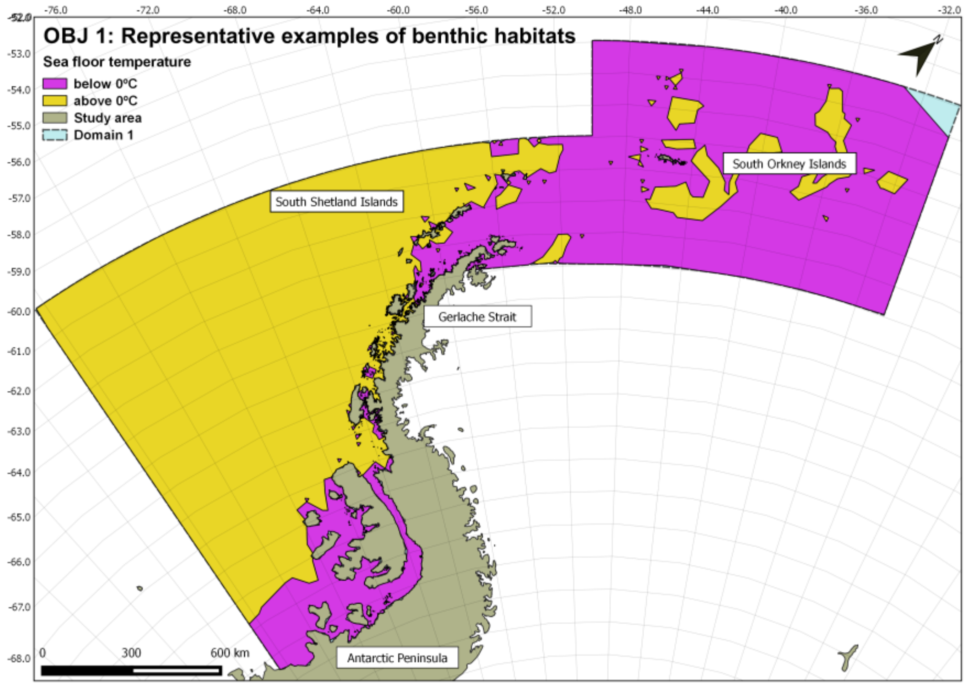

Figure 1c: Bottom sea temperatures above and below 0°C as a proxy to identify benthic invertebrate communities extracted from the World Ocean Atlas.

Conservation Objective 2: Representative examples of pelagic habitats

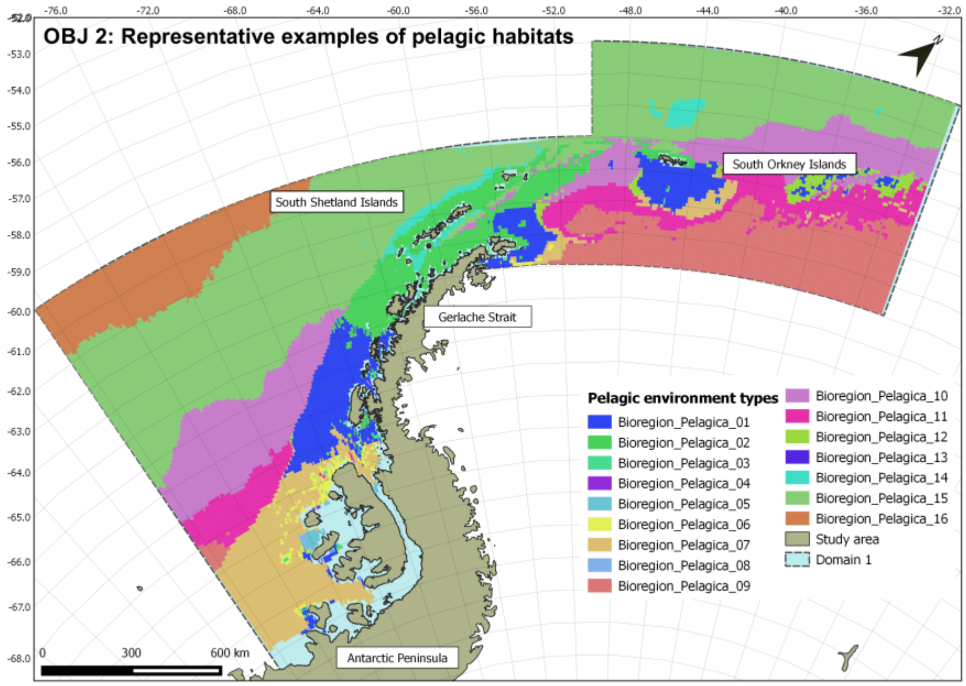

Figure 2: Pelagic habitats as defined in Raymond 2011, reduced to fit Domain 1.

Conservation Objective 3 – Important benthic ecosystem processes

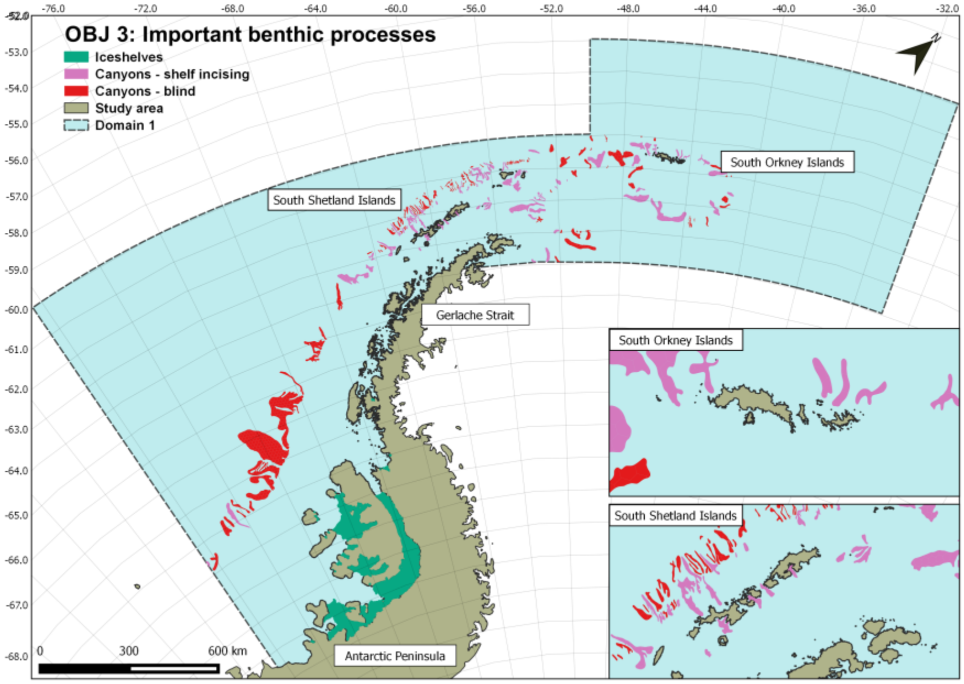

Figure 3: Distribution of shelf incising canyons, blind canyons (from Harris et al. 2014) and ice-shelves.

Conservation Objective 4: Large-scale pelagic ecosystem processes

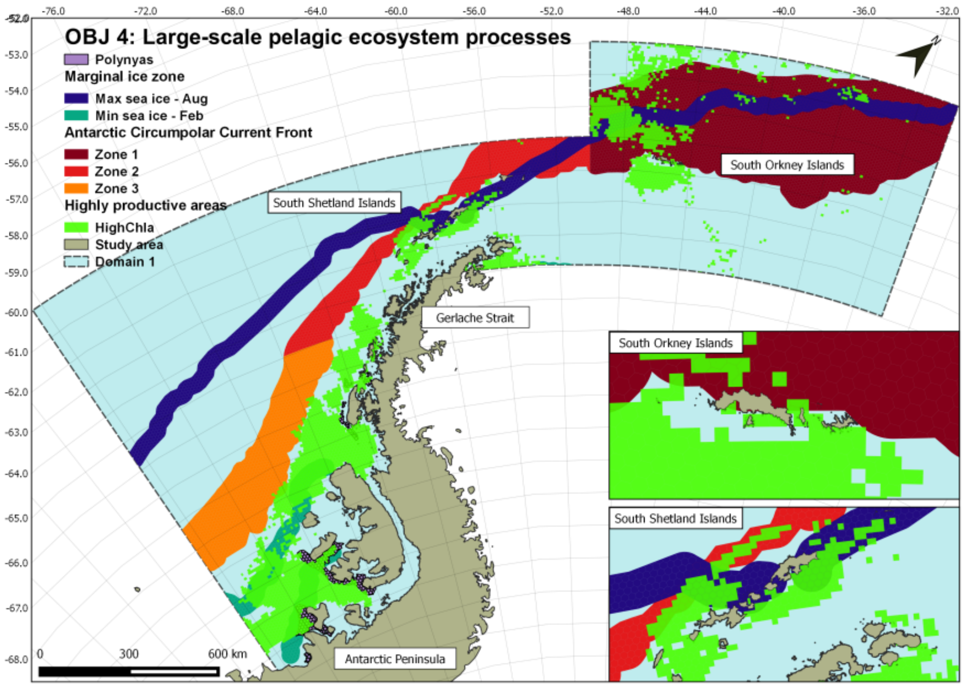

Figure 4: Distribution of pelagic process including polynyas, marginal ice zones (summer and winter), Antarctic Circumpolar Front (divided in three zones: east /west of the 50°W meridian and north/south the Anvers Island), and highly productive areas (surface).

Conservation Objective 5 - Important areas for predators life-history.

5a) Foraging distributions of Central Place Foragers during breeding season

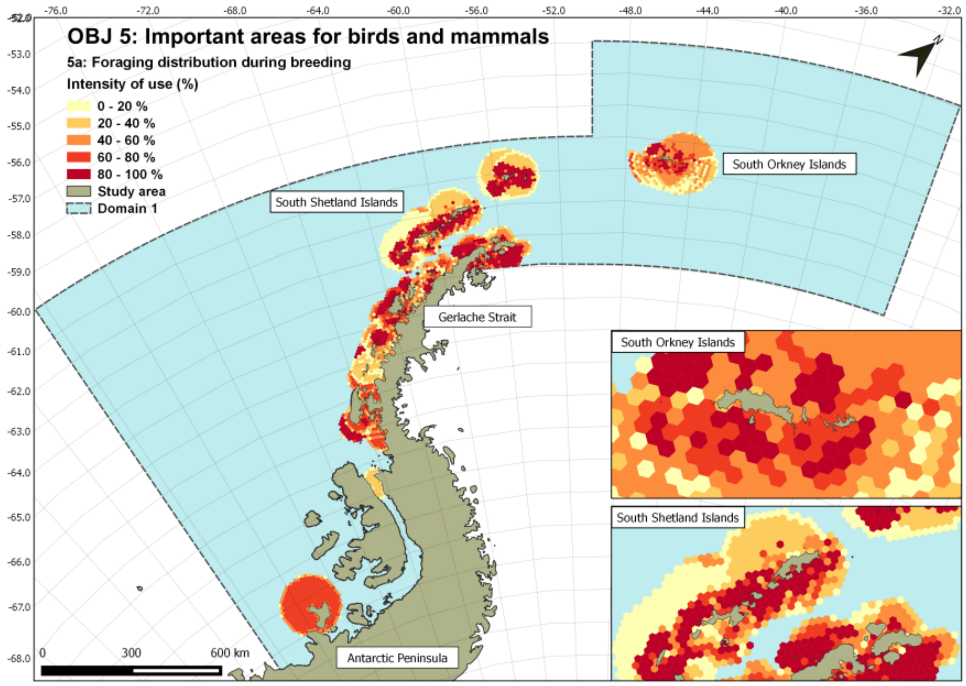

Figure 5a: Intensity of use for Domain 1 by Adélie penguins, chinstrap penguins, gentoo penguin, emperor penguins and fur seals based on colonies locations and foraging distribution during breeding season.

Objective 5b: Prey distribution

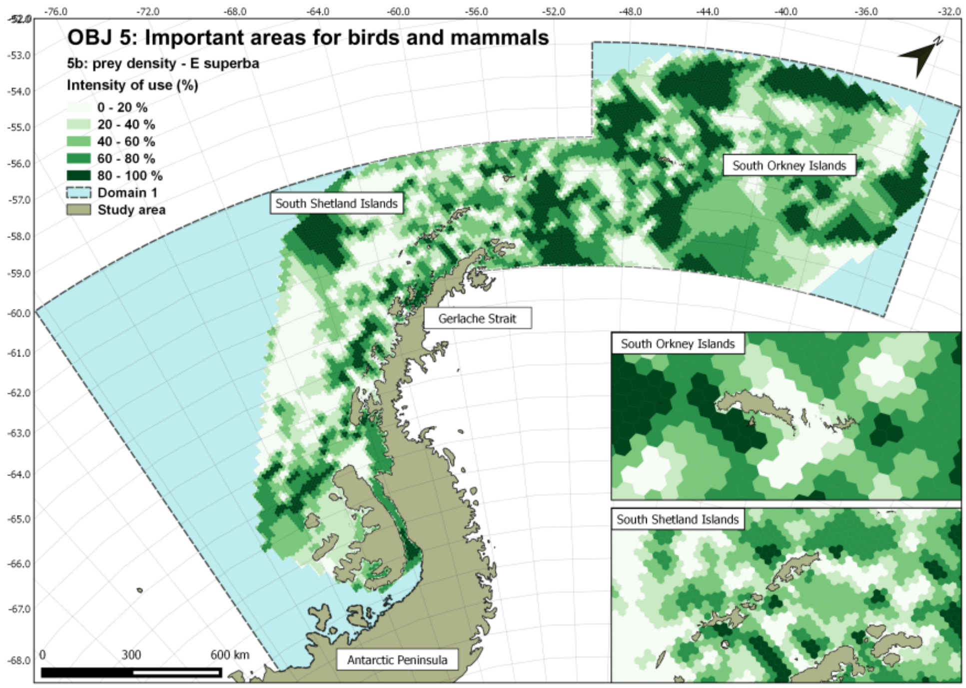

Figure 5b: Density for Antarctic krill (*Euphausia superba*) estimated from standardized density data compiled from the KRILLBASE for the period 1993-2011 (Atkinson et al. 2017).

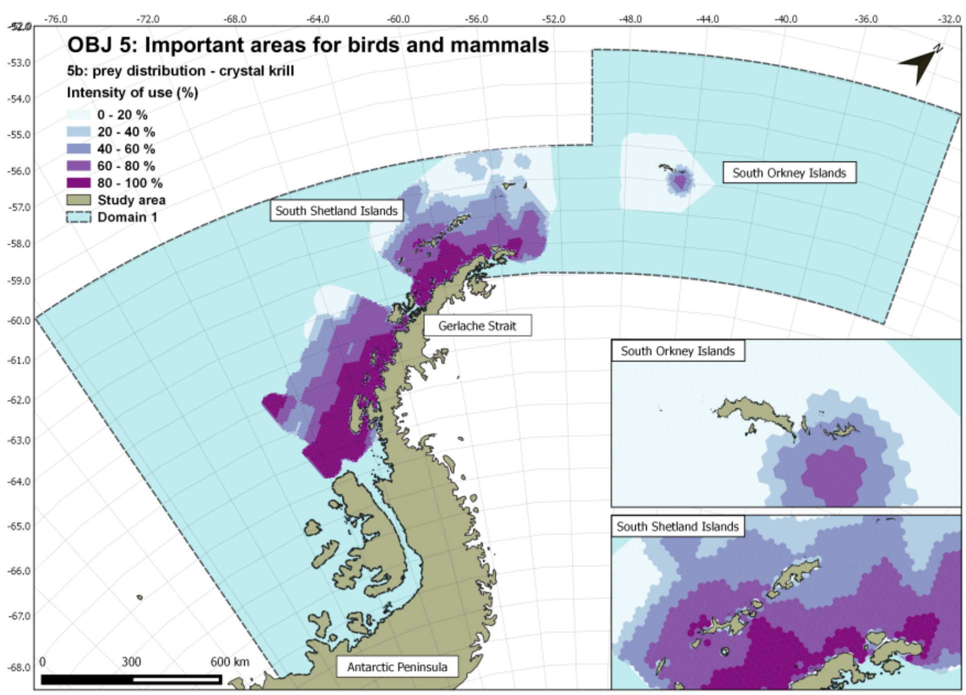

Figure 5c: Density for crystal krill (*E. crystallorophia*) estimated from zoooplankton density data collected by U.S. AMLR Program during net tow surveys (1993-2011) and PAL LTER).

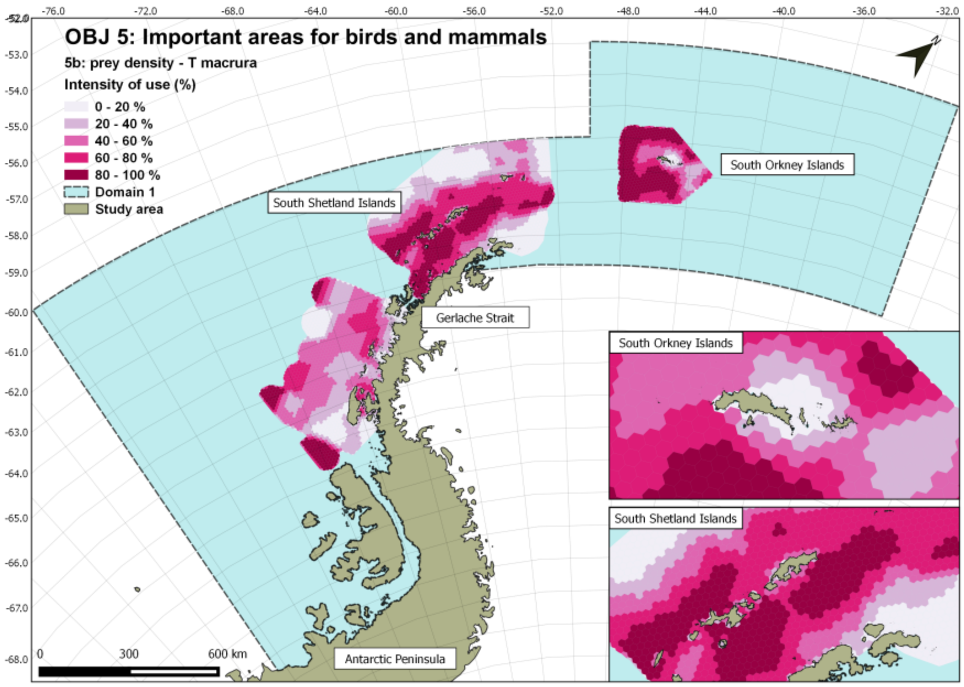

Figure 5d: Density for *Thysanoessa macrura* estimated from zoooplankton density data collected by U.S. AMLR Program during net tow surveys (1993-2011) and PAL LTER.

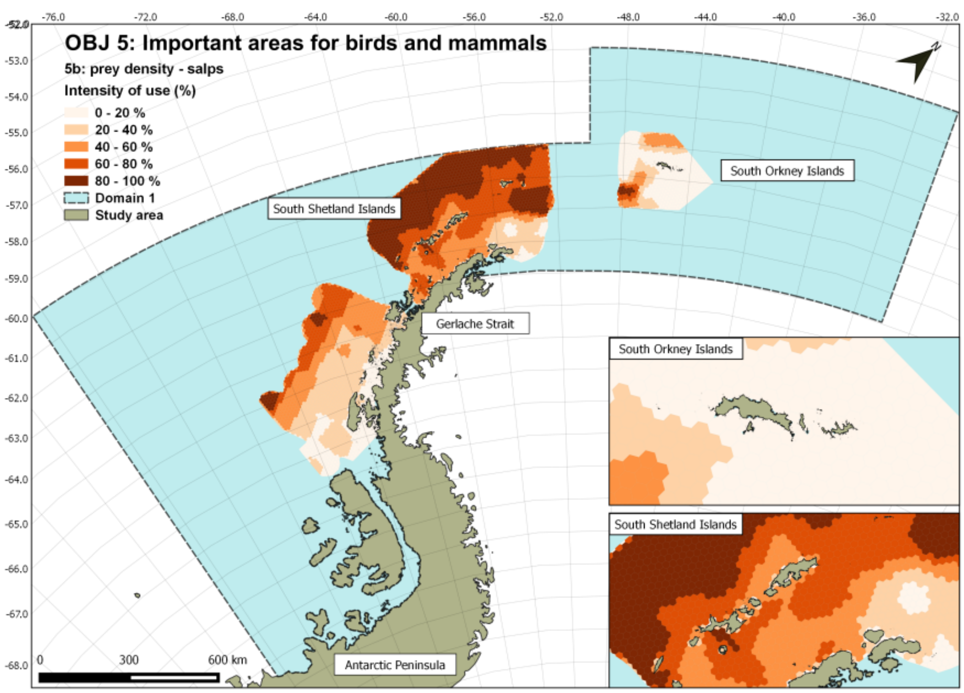

Figure 5e: Density for salps (*Salpa thompsoni*) estimated from zoooplankton density data collected by U.S. AMLR Program during net tow surveys (1993-2011) and PAL LTER

Objective 5c: feeding distribution during non-breeding periods

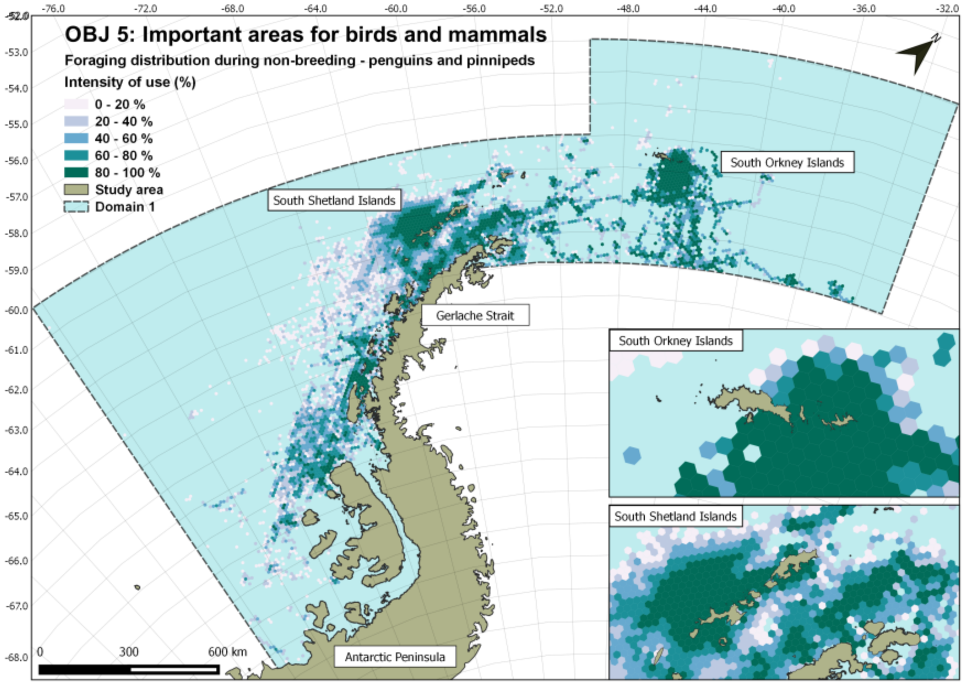

Figure 5f: Intensity of use of Domain 1 by pygoscelid penguins and pinnipeds during non-breeding season.

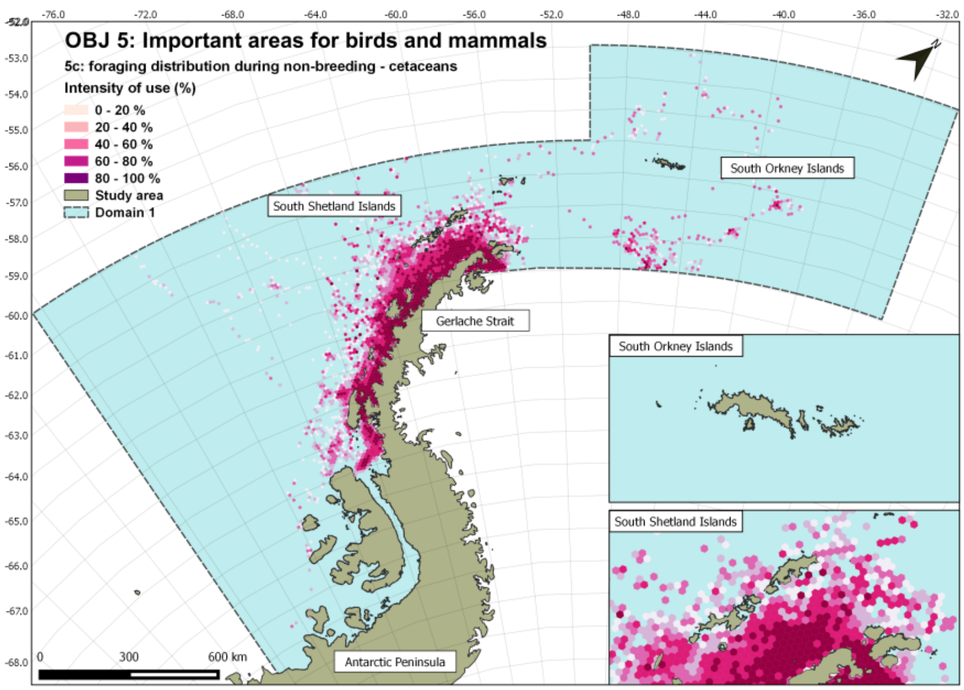

Figure 5g: Intensity of use of Domain 1 by cetaceans during non-breeding season.

Conservation Objective 6: Important (spatially constrained/predictable) areas for fish life cycles

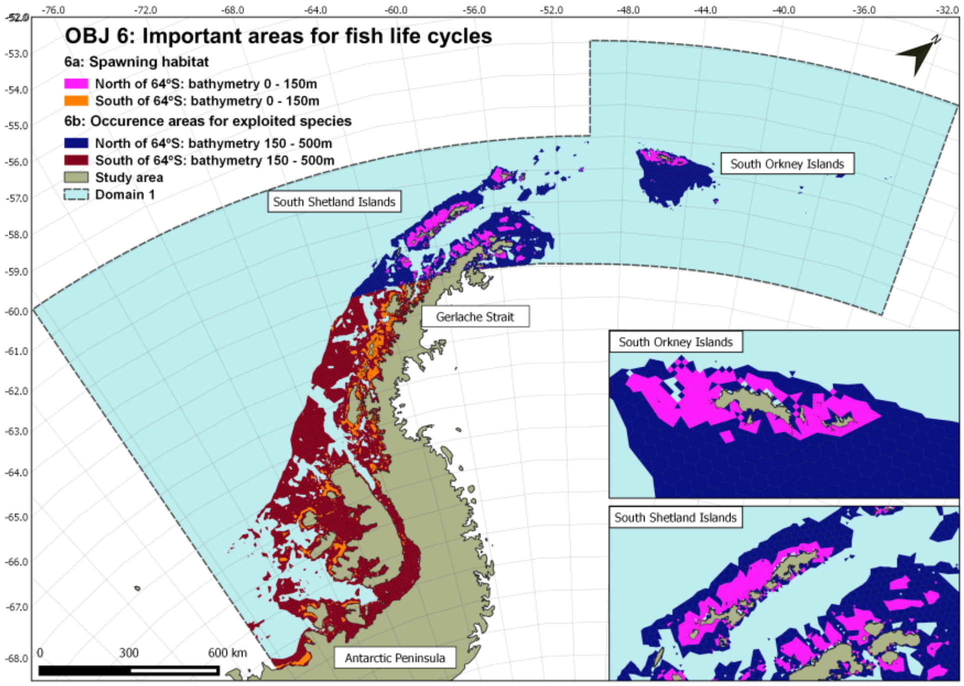

Figure 6: Important areas for fish life cycles, including spawning/early stages habitat (0-150 m), and occurrence area (150-500 m) for exploited species.

Conservation Objective 7: Important (spatially constrained/predictable) areas for zooplankton-life cycles.

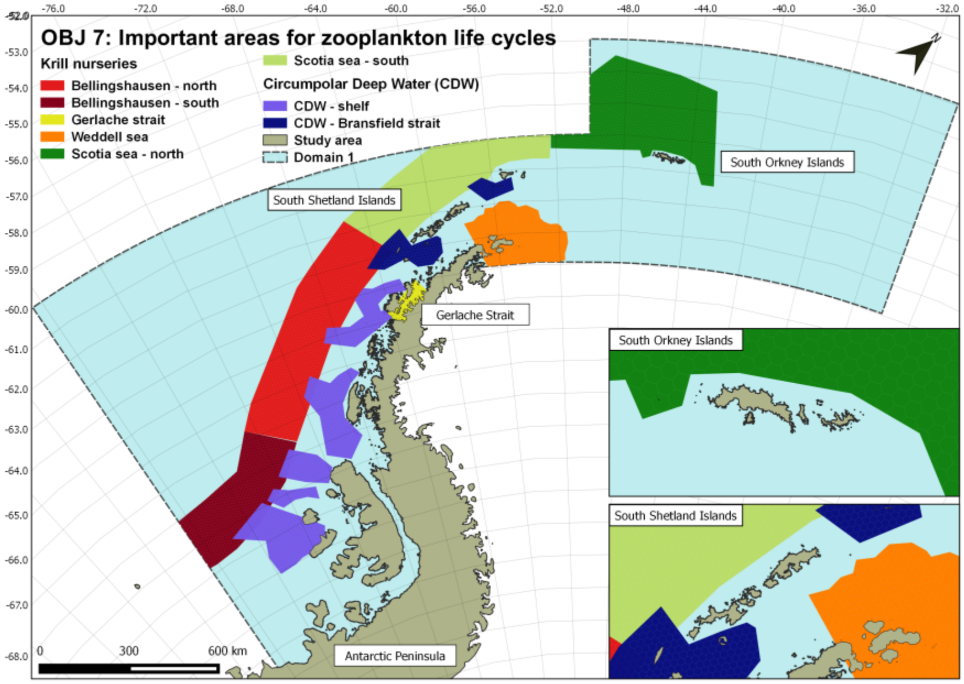

Figure 7: Location of krill nurseries in the Weddell Sea, Scotia Sea, Bellinghausen Sea, and Gerlache Strait, and location of the Circumpolar Deep Water Current.

Conservation Objective 8: Rare or unique habitats/features

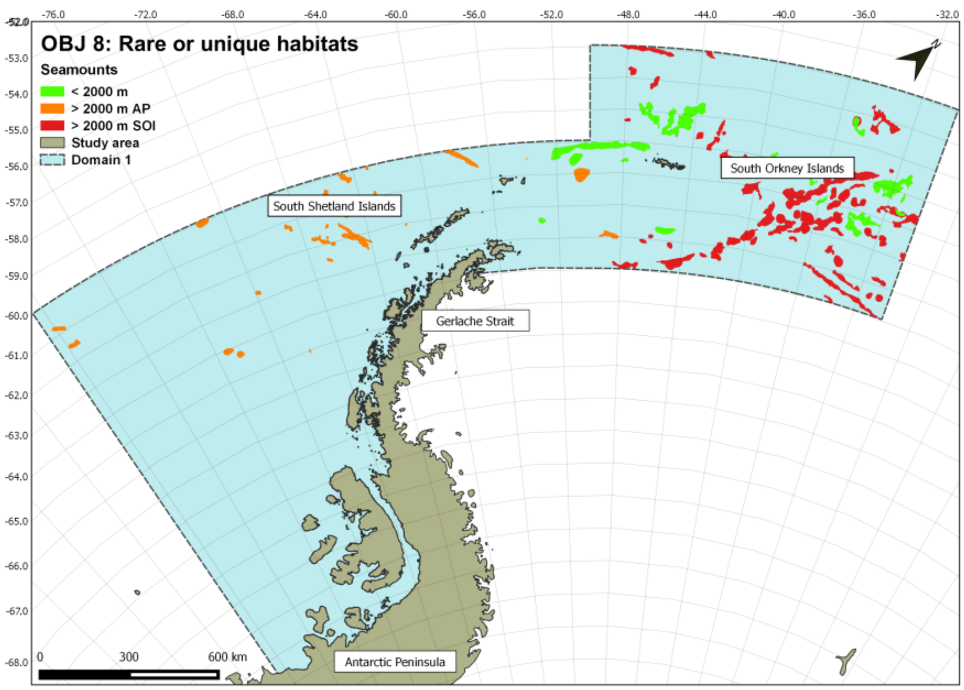

Figure 8: Distribution of seamounts based on the Global Seafloor Geomorphology database

Annex 2. Table A. Conservation objectives, objects and targets agreed for Domain 1 MPA planning process.

CONSERVATION OBJECTIVE		CONSERVATION OBJECT	CONSERVATION TARGET
OBJECTIVE 1: Representative examples of benthic habitats	Benthic ecoregions	South Orkneys	10
		Western Antarctic Peninsula	10
		Pacific Basin	10
	Bottom temperature	Sea floor temp <0°C	10
		Sea floor temp >0°C	10
	Benthic environment types	Benthic bioregionalization (66 features)	10
OBJECTIVE 2: Representative examples of pelagic habitats	Pelagic environment types	Pelagic bioregions (16 features)	10
OBJECTIVE 3: Important benthic processes	Benthic areas under ice shelves	Ice-shelves	20
	Canyons	Canyons shelf incising	50
		Canyons blind	50
	Frontal features (Antarctic Circumpolar Current Front)	ACCf_Zone1	20
		ACCf_Zone2	20
		ACCf_Zone3	20
OBJECTIVE 4: Large-scale pelagic ecosystem processes	Highly productive areas	High Chla	30
	Marginal ice zone	Sea Ice_Aug	20
		Sea Ice_Feb	20
	Polynyas	Polynyas	50
OBJECTIVE 5: Important areas for mammals and birds life-histories	5a: Breeding foraging distribution	Adélie penguin - SOr1	50
		Adélie penguin - SSr2	50
		Adélie penguin - SSr3	50
		Chinstrap penguin - SOr1	50
		Chinstrap penguin - SSr2	50
		Chinstrap penguin - SSr3	50
		Gentoo penguin - SOr1	50
		Gentoo penguin - SSr2	50
		Gentoo penguin - SSr3	50
		Emperor penguin - Weddell	50
		Emperor penguin - WAP	50
		Fur seals	50
	5b: Prey distribution	Crystal krill	20

		E. superba	20
		Salps	20
		T. macrura	50
	5c: Non-breeding foraging distribution	Adelie penguin - SS	50
		Adelie penguin - SO	50
		Gentoo penguin - SS	50
		Chinstrap penguin	50
		Chinstrap penguin - SO	50
		Fur seal	50
		Leopard seal	50
		Weddell seal	50
		Elephant seal	50
		Minke whale	50
		Humpback whale	50
		Killer whalet ype A	50
		Killer whale type B1	50
		Killer whale type B2	50
OBJECTIVE 6: Important areas for fish life cycles	6a: Spawning/early stages habitat	North of 64S:0m to 150m	80
		South of 64S:0m to 150m	20
	6b: Occurence areas for exploited species	North of 64S:150m to 500m	30
		South of 64S:150m to 500m	20
OBJECTIVE 7: Important areas for zooplankton life cycles	Krill nursery	Bellinghausen_N_nursery	20
		Bellinghausen_S_nursery	20
		Gerlache Strait_nursery	100
		Weddell Sea_nursery	20
		ScotiaSea_SS_nursery	20
		ScotiaSea_SOI_nursery	5
	Circumpolar deep water	CDW_shelf	70
		CDW_BS	70
OBJECTIVE 8: Rare or unique habitats	Seamounts	Seamounts <2000m	50
		Seamounts >2000m AP	10
		Seamounts >2000m SOI	10

Annex 3. List of participants of Domain 1 MPA workshops.

WS- DOMAIN 1 2012		
Name	**Country**	**Institution**
David Ramm	CCAMLR	CCAMLR
Javier Arata	Convener-Chile	Instituto Antártico Chileno
Enrique Marschoff	Convener-Argentina	Instituto Antártico Argentino
Esteban Barrera Oro	Argentina	Instituto Antártico Argentino
Mercedes Santos	Argentina	Instituto Antártico Argentino
Patricia Martinez	Argentina	INIDEP
Gustavo San Martín	Chile	Subsecretaría de Pesca
Carlos Gaymer	Chile	Universidad Católica del Norte
Francisco Squeo	Chile	Universidad de la Serena-CEAZA -IEB
Patricio Arana	Chile	Universidad Católica de Valparaíso
Taro Ichii	Japan	Research Institute of Far Seas Fisheries
Mari Mishima	Japan	Fisheries Agency of Japan
Erlend Moksness	Norway	Institute of Marine Research
Susie Grant	United Kingdom	British Antarctic Survey
Phil Trathan	United Kingdom	British Antarctic Survey
Chris Reiss	USA	Southwest Fisheries Science Center, National Marine Fisheries Service
Doug Nowacek	USA	NSF-OPP-LTER
Enrique Le Dantec	Industry observer-Chile	Antarctic Sea Fisheries
Enrique Gutiérrez	Industry observer-Chile	Pesca Chile
Beatriz Ramírez	Chile	Ministerio Medio Ambiente
Veronica Cirelli	Argentina	ASOC
Rodolfo Werner	Argentina	ASOC
Lucinda Douglass	Australia	Centre for Conservation Geography / University of Queensland
Matthias Gorny	Chile	Oceana
Layla Osman	Chile	The Nature Conservancy

WS- DOMAIN 1 2015		
Name	**Country**	**Institution**
Enrique Marschoff	Argentina	Instituto Antártico Argentino
Esteban Barrera Oro	Argentina	Instituto Antártico Argentino
Mercedes Santos	Argentina	Instituto Antártico Argentino
Andrea Capurro	Argentina	Dirección Nacional del Antártico
Jose Luis Orgeira	Argentina	Instituto Antártico Argentino
Viviana Alder	Argentina	Instituto Antártico Argentino
Hernán Sala	Argentina	Instituto Antártico Argentino
Liliana Quartino	Argentina	Instituto Antártico Argentino
Silvia Romero	Argentina	Servicio de Oceanografía Naval
Facundo Alvarez	Argentina	Instituto Antártico Argentino
Sandra Vivequin	Argentina	Instituto Antártico Argentino
Verónica Vlasich	Argentina	Dirección Nacional del Antártico
Odile Hourcade	Argentina	Dirección Nacional del Antártico
Esteban Gaitan	Argentina	Instituto Nacional de Investigación y Desarrollo Pesquero
Javier Arata	Chile	Instituto Antártico Chileno
Patricia Brtnik	Germany	German Oceanographic Museum
Georg Skaret	Norway	Institute of Marine Research
Jefferson Hinke	United States	Southwest Fisheries Science Center, National Marine Fisheries Service
George Watters	United States	Southwest Fisheries Science Center, National Marine Fisheries Service
SusieGrant	United Kingdom	British Antarctic Survey
Phil Trathan	United Kingdom	British Antarctic Survey
Roberto Sarralde	European Union	Instituto Español Oceanográfico
Rodolfo Werner	Argentina	ASOC
Lucinda Douglass	Australia	Centre for Conservation Geography / University of Queensland
Esteban Frere	Argentina	Bird Life Intl
Enrique Le Dantec	Chile	Antarctic Sea Fisheries